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USE OF THE WATER, ENERGY, AND BIOGEOCHEMICAL MODEL (WEBMOD) AND THE SOIL AND WATER ASSESSMENT TOOL (SWAT) TO IDENTIFY HYDROLOGIC FLOW PATHS AT FIVE AGRICULTURAL SITES INCLUDED IN THE U.S. GEOLOGICAL SURVEY NATIONAL WATER-QUALITY ASSESSMENT (NAWQA) PROGRAM

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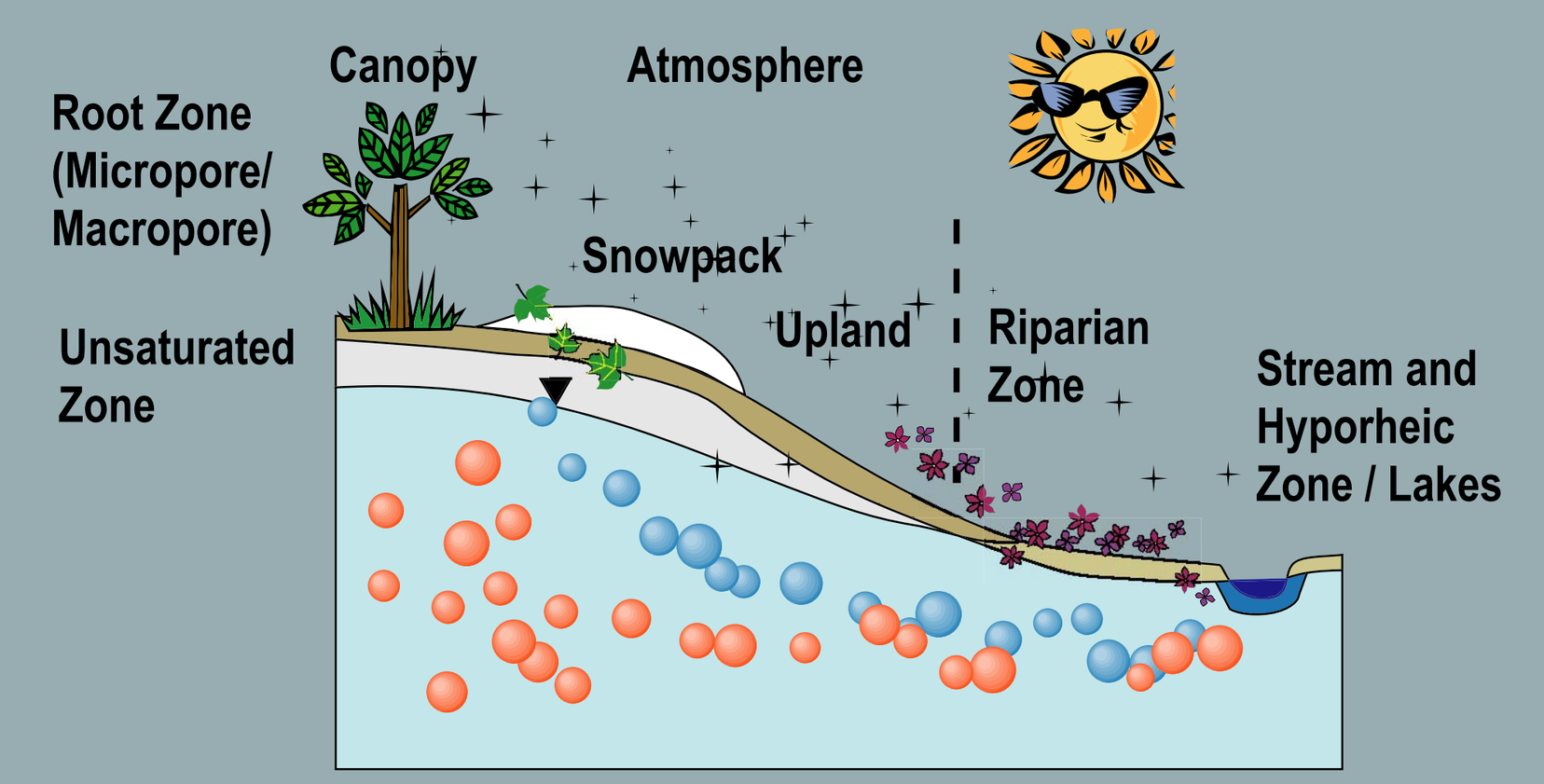
BACKGROUND AND OBJECTIVE

As part of the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program, the transport and fate of nutrients and agricultural chemicals are being studied at five sites with significantly different climate, surficial geology, crops, and agricultural practices: Mustang Creek in California; Granger Drain in Washington; Maple Creek in Nebraska; Sugar Creek in Indiana; and Morgan Creek in Maryland. WEBMOD and SWAT are being tested to see how well they simulate variations in discharge and water quality measured at the sites. The work presented here forms part of out initial efforts to answer three questions: 1) What are the primary streamflow-generation processes in generally flat agricultural landscapes? 2) How do the fluxes of water and conservative solutes predicted by SWAT, which uses a curve-number method, compare with those predicted by WEBMOD, which is a more process based model? 3) Is the reliability of model-estimated discharge and water quality improved by calibrating the models to measured concentrations of chemical tracers, such as chloride and base cations?

Figure 1. Locations of the five NAWQA study units where the transport and fate of agricultural chemicals is being studied

TRACERS AND FLOW PATHS



TRACERS

Potassium: Potassium is a nutrient that is rapidly assimilated by vegetation therefore it is found only in the shallowest horizons.

DOC: Organic carbon is actively cycled by biota in the shallow layers of the soils. Spikes in DOC are indicative of infiltration excess or saturated overland flows.

Chloride: Atmospheric deposition is almost always the only source of chloride. Before any calculations of bedrock weathering can be made, the estimated input of major ions from atmospheric deposition is usually subtracted in proportions found in sea salt.

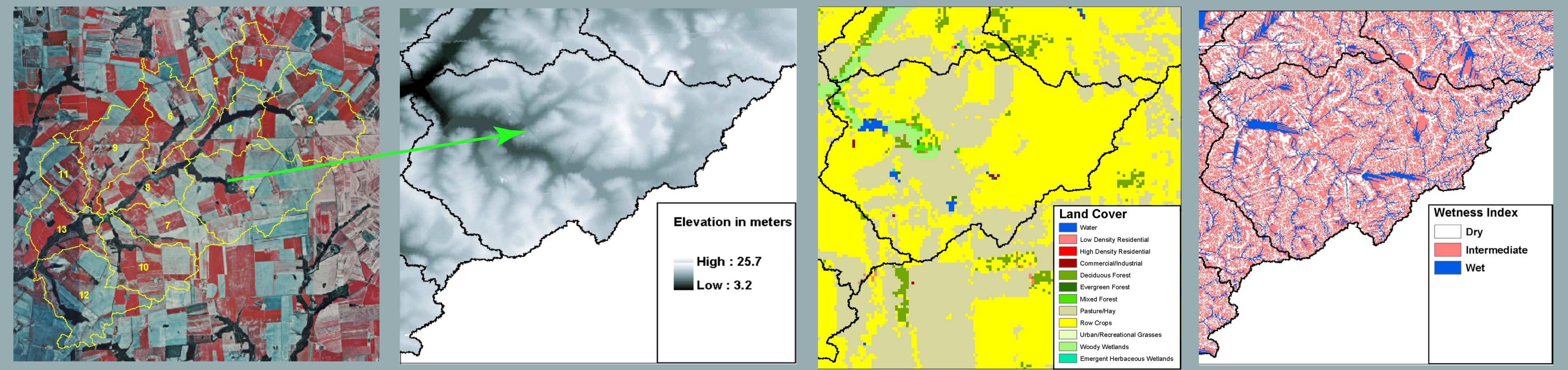
Oxygen isotopes: Rainwater becomes istopically lighter with increasing distance from the coast. Fractionation during freezing results in snow being significantly lighter than rain. Along with deuterium and tritium, this is a favorite tracer for hydrologic systems because it 'is' the water of interest. In addition to seasonal variations, del 18O will shift in response to evaporation from open water bodies.

Bedrock Alkalinity: Soils form as dilute acids in rainfall dissolve and disaggregate minerals producing cations and hydroxide. This tracer dominates during base flows and also forms a significant part of the initial flush of the deep soils by heavy rainfall or spring melt.

INPUTS → LANDSCAPES → OUTPUTS

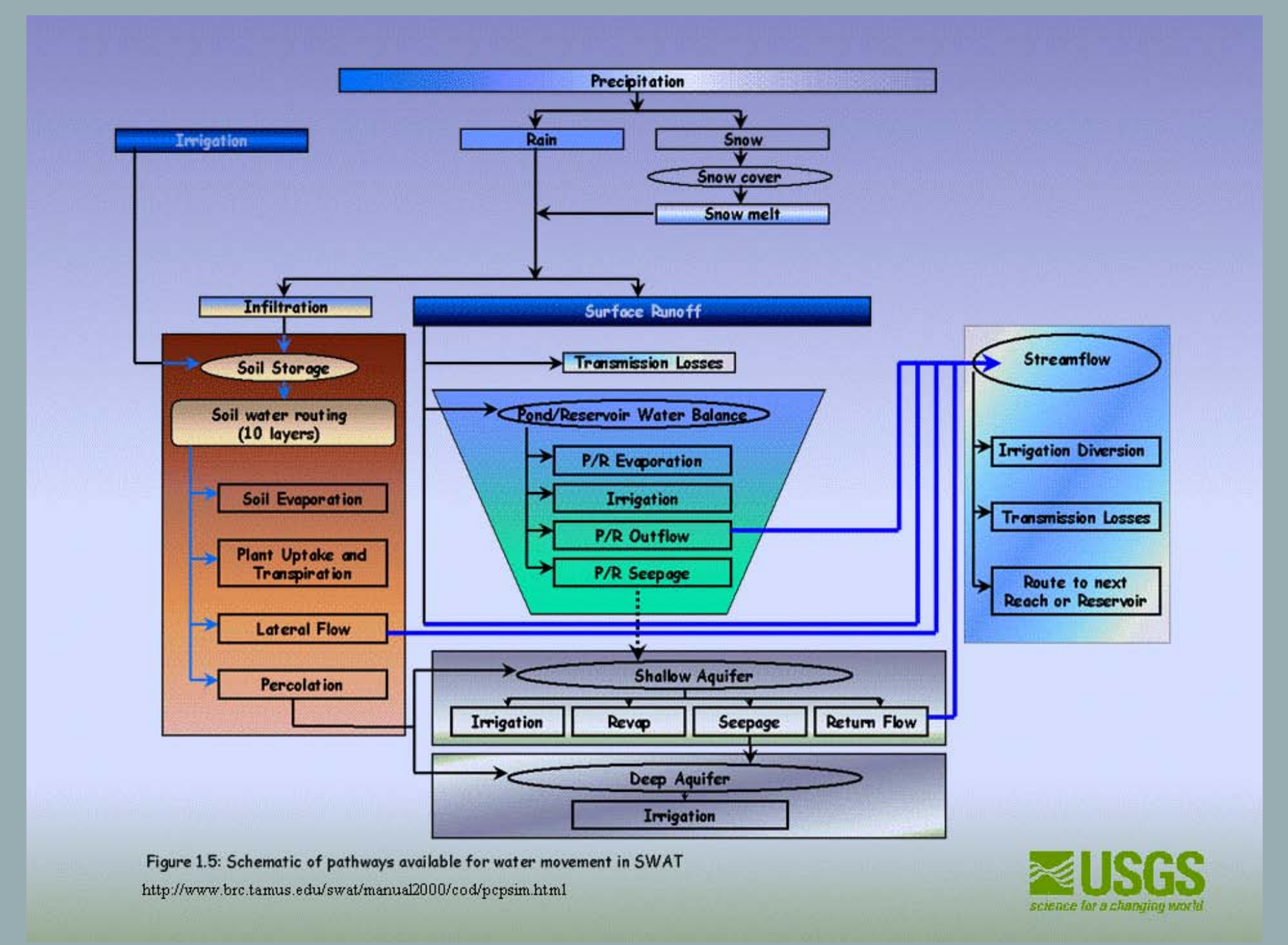
Figure 2. Snowmelt, precipitation and irrigation transport agricultural chemicals from the fields, through the landscapes, and into the streams. The route that the water and solutes take on the way to the stream can has a profound effect on the water quality in the unsaturated zone, the saturated zone, and the streams and rivers. One of the principal objectives of the National Water Quality Assessment is to improve our understanding of the flow paths and stream flow generation mechanisms so that the loads of agricultural chemicals reaching the streams are reduced. A variety of natural and anthropogenic tracers are available for evaluating the ability of watershed models to simulate the fate and transport of agricultural chemicals so that the insight gained at the intensive study sites can be transferred to other areas. This presentation discusses the initial application of SWAT and WEBMOD to the study unit.

MODELS AND DISCRETIZATION



CROP TYPES AND AG PRACTICES | DIGITAL ELEVATION MODEL | LAND COVER | WETNESS INDICES

Figure 3. Imagery and spatial derivatives for the Morgan Creek watershed in the Potomac-Delmarva Study Unit. Both SWAT and WEBMOD are semidistributed hydrologic models that need elevation and land cover data as input. In SWAT, streams receive runoff and groundwater discharge from a subcatchment that can be further divided into smaller hydrologic response units (HRU's) that have similar soils and or land cover. In contrast, WEBMOD uses TOPMODEL algorithms to simulate a variety of streamflow generation mechanisms. The fundamental discretization in TOPMODEL is the wetness index, ln(a/tanB), where 'a' is the contributing area upstream of a given point and 'tanB' is the slope of the the land surface. Thus areas of convergence (greater 'a') or flatter slopes are expected to be wetter than convex areas with high slopes. The figure above displays three wetness-index classes whereas in practice, parameters for vegetation and land cover are commonly derived for more than 20 index bins in each subcatchment. The derivation of spatial parameters is facilitated by the use of a geographic information system.



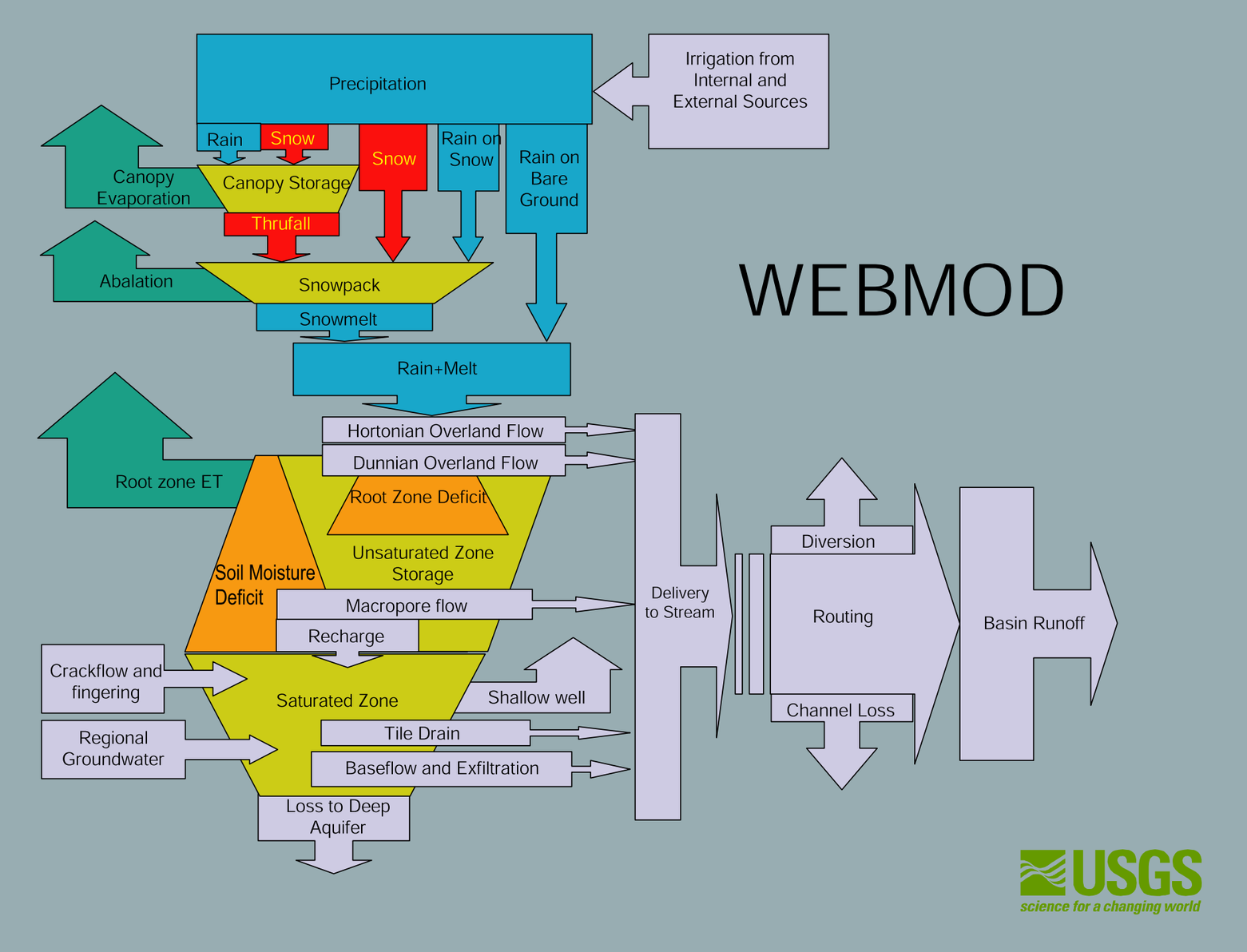


Figure 4. SWAT will simulate infiltration and runoff for each HRU and then average the predicted fluxes of water and solutes for delivery to the stream. WEBMOD distributes temperature and precipitation using algorithms from the Precipitation Runoff Modeling system (Leavesley and others, 1983). Snowpack processes are simulated using an index temperature method using the National Weather Service.

PRELIMINARY RESULTS

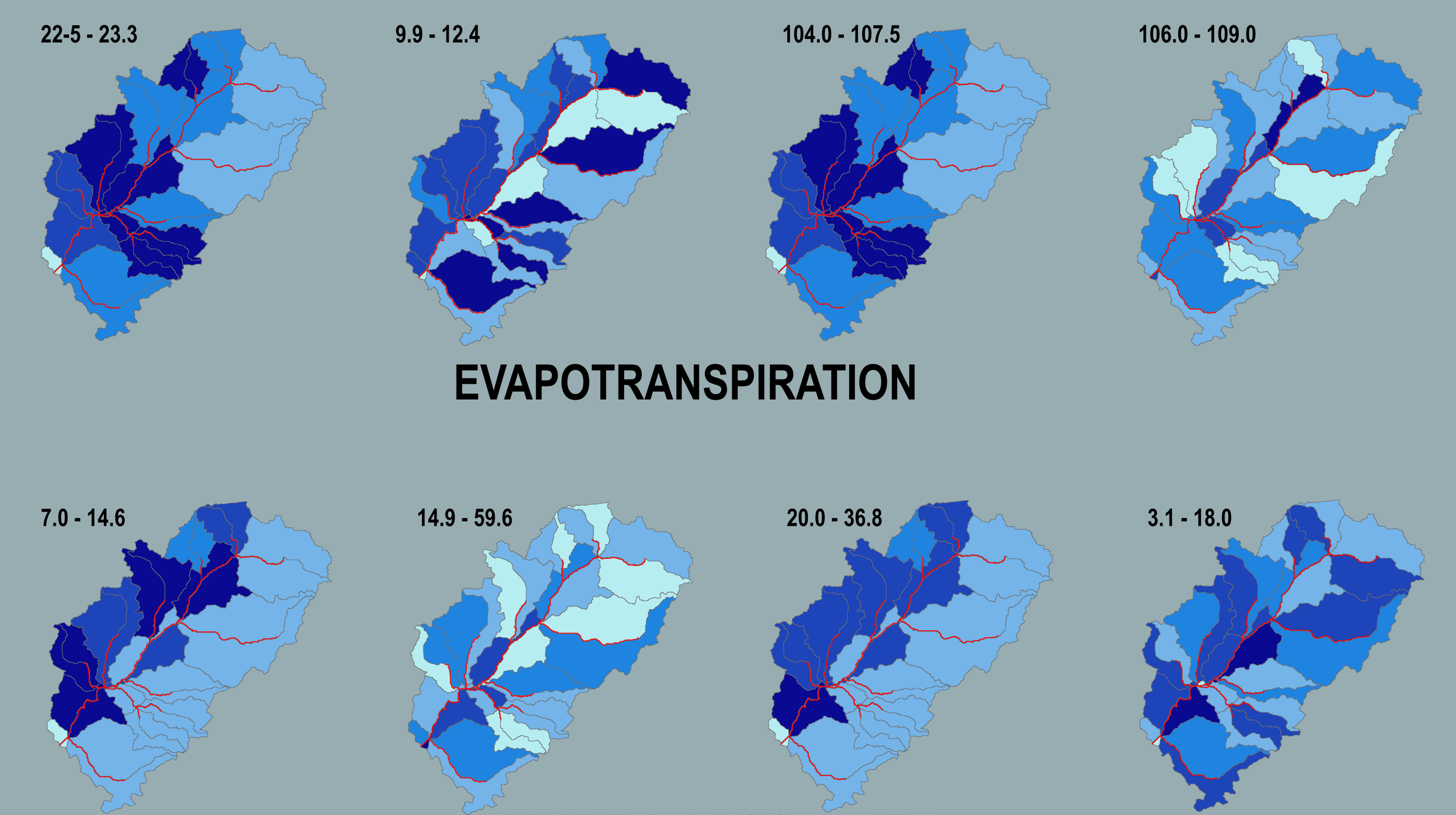
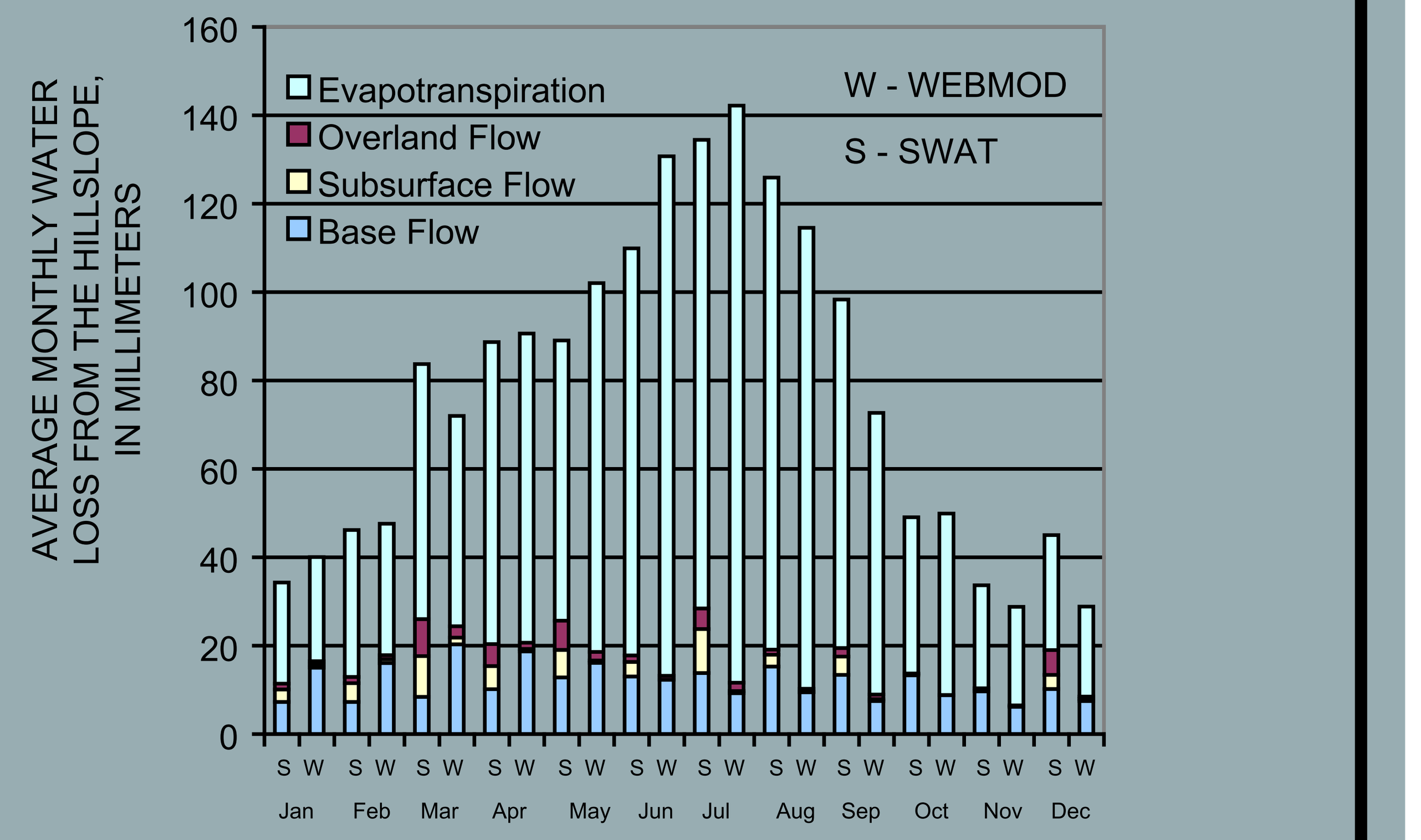


Figure 5. Average monthly depth, in millimeters, of evapotranspiration and hillslope discharge for the Morgan Creek watershed in the Potomac-Delmarva Study Unit. The models were run from January 2000 through April of 2002 and the average values for Winter (January) and Summer (July) are shown above. The numbers adjacent to the basin figures indicate the range of values included in the shades of blue. The lightest blue indicates the lower end of the range. WEBMOD was originally applied in mountainous watersheds and left and right banks were commonly separated out. Thus WEBMOD does a good job in simulating variable solar loadings, whereas the plant models and their potential effect and dependence on the hydrology, are more advanced in SWAT.

DISCUSSION

Figure 6. Average monthly water exported from the hillslopes for the entire Morgan Creek basin, in millimeters. For each month, SWAT-predicted fluxes precede those of WEBMOD. Note that even though more water is available in the summer, discharge is greatest in the spring, before photosynthesis becomes significant. Both SWAT and WEBMOD are capable of obtaining good fits to observed hydrographs. However, it is believed that the finer level of discretization and the ability to simulate variable source contributions will enable WEBMOD to excel at simulating both conservative and reactive solute transport through diverse landscapes. The first round of tracer data has been collected. When the results become available, objective functions including both hydrologic and geochemical members will be used to evaluate the solute transport capabilities of SWAT and WEBMOD.



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Internet sites for more info

USGS NAWQA Program: http://water.usgs.gov/nawqa
USGS Modular Modeling System: http://wwwbrr.cr.usgs.gov/mms/
USGS PHREEQC: http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/index.html
Lancaster TOPMODEL/GLUE: http://www.es.lancs.ac.uk/hfdg/hfdg.html
SWAT: http://www.brc.tamus.edu/swat/